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Bioremediation of Contaminated Soil Using Land Treatment Processes

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Outline

- Overview of Soil Treatment Processes
- Biological Treatment Fundamentals
  - Contaminants Amenable to Landfarming
- Traditional Land Treatment Units
  - Design
  - Construction
  - Operation
- Low Cost & Passive Land Treatment Strategies
- Resources / Contacts

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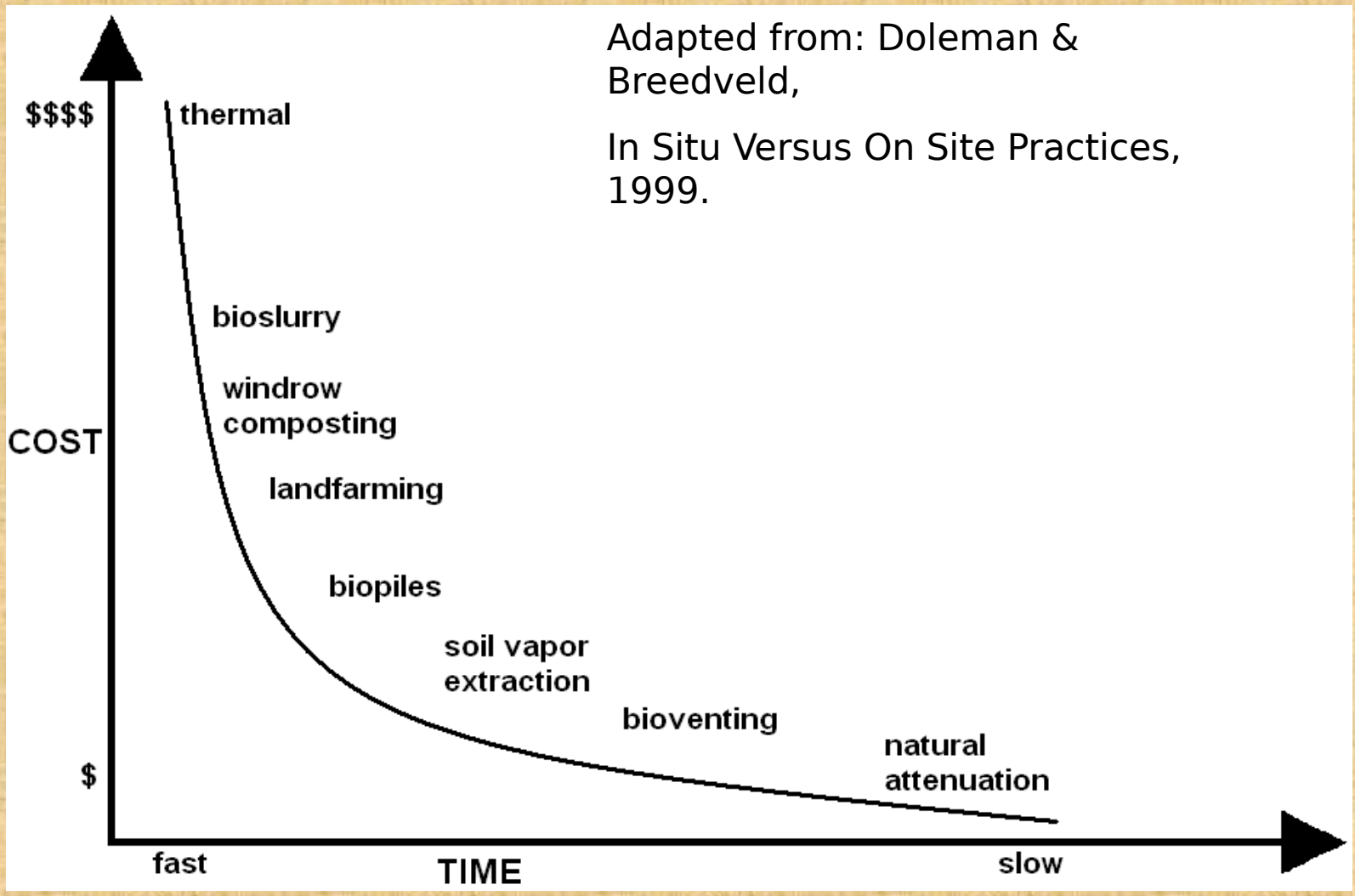
Overview of Contaminated Soil Treatment Processes



Adapted from: Doleman & Breedveld,

In Situ Versus On Site Practices, 1999.

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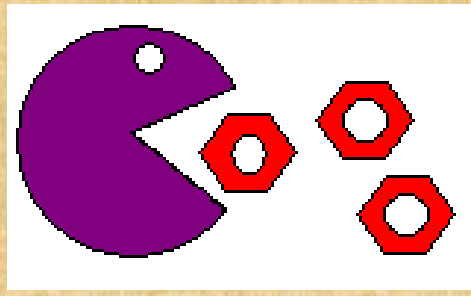
Biological Treatment Fundamentals

Humans

- **Carbon source: Food**
- **Energy source (electron donor): Food**
- **Respiration (electron acceptor): Oxygen**



- **Bacteria**
- **Carbon source: Petroleum hydrocarbons**
- **Energy source (electron donor): Petroleum hydrocarbons**
- **Respiration (electron acceptor): Oxygen (aerobic bacteria)**

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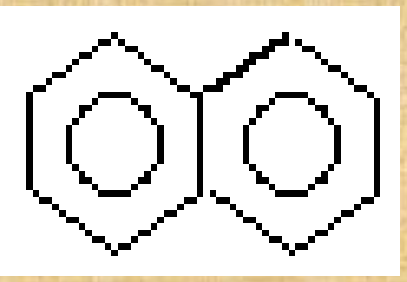
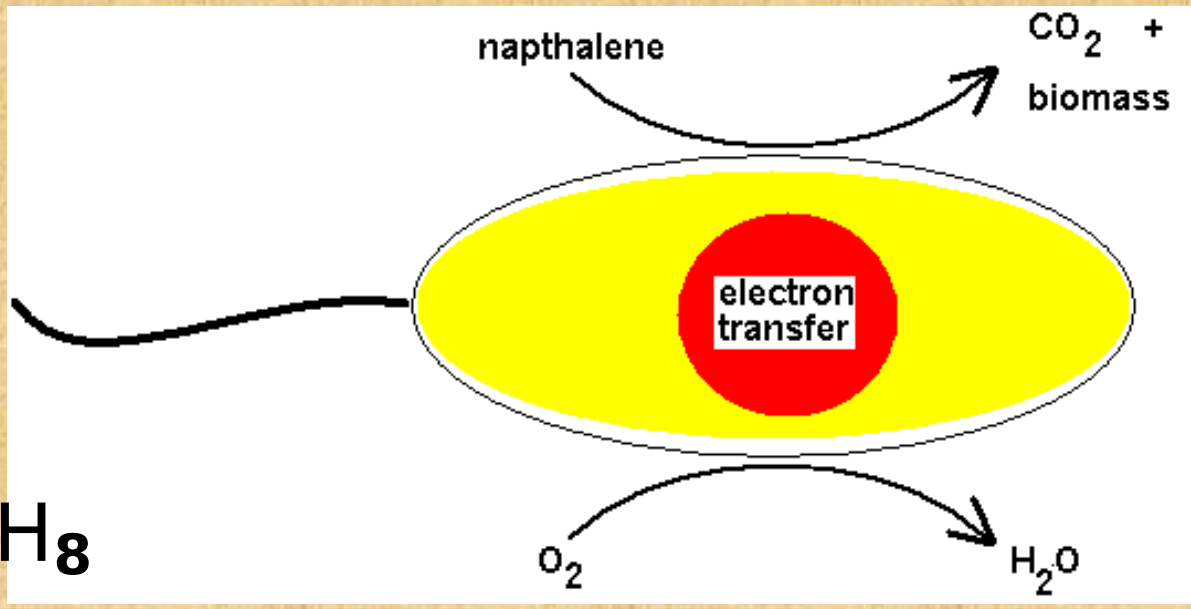
Biological Treatment Fundamentals





naphthalene=$C_{10}H_8$

$C_{10}H_8 + 12\ O_2 \dashrightarrow 10\ CO_2 + 4\ H_2O$

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Contaminants Amenable to Landfarming

- **Petroleum products**
  - **Jet fuel, diesel, heating oil, motor oil**
  - **crude oil, petroleum refinery sludge**
- **Wood treatment chemicals**
  - **Creosote (polyaromatic hydrocarbons = PAHs)**
  - **Pentachlorophenol**

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Traditional Land Treatment Units (LTUs)

- Design
- Construction
- Operation

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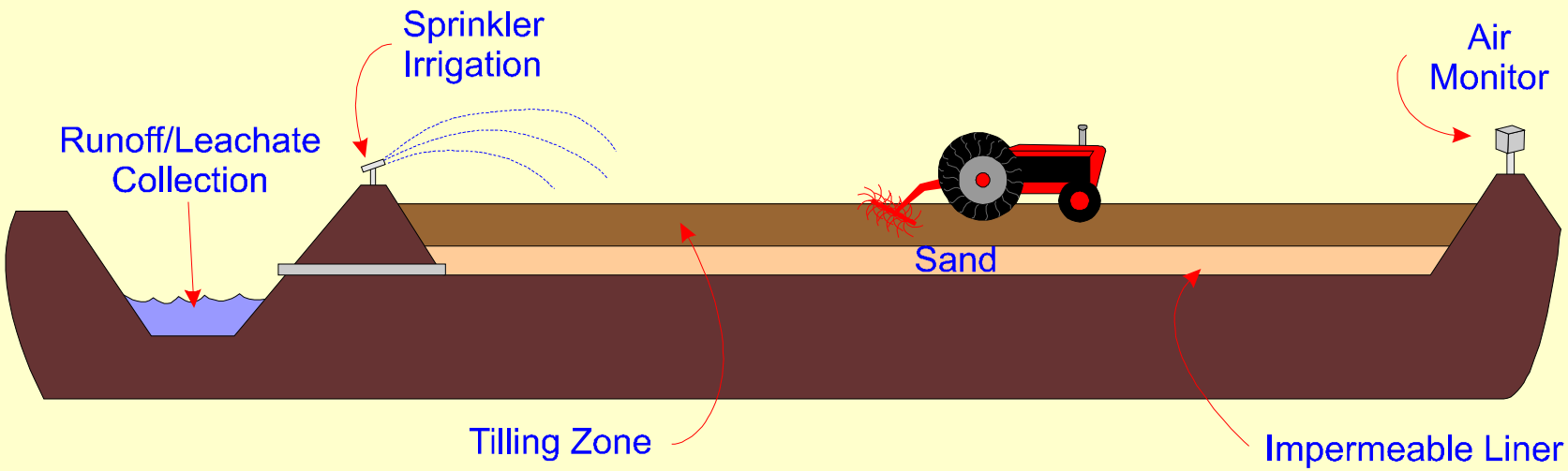
Traditional LTU: Design

LTU with impermeable liner & leachate collectio



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Traditional LTU: Construction

- Grading of LTU area
- Construction of water management system
  - Dikes & berms
  - Lined water collection pond
- Installation of impermeable liner (if used) & drainage layer
- Irrigation equipment
- Photos courtesy of Jim Harris, P.E., USEPA

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Installation of impermeable liner

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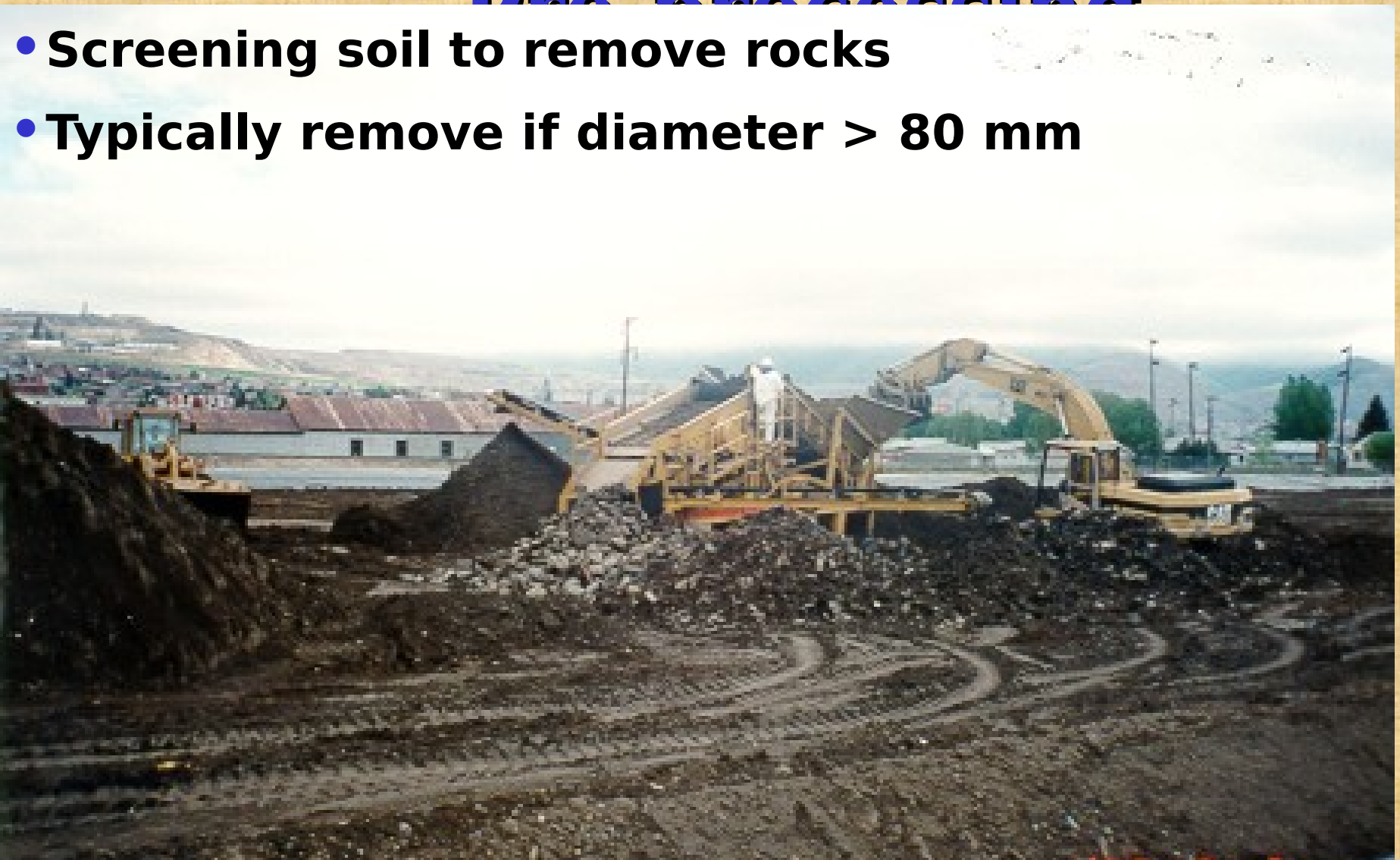
Traditional LTU: Operation Excavation and Pre-processing

- Screening soil to remove rocks
- Typically remove if diameter > 80 mm



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Traditional LTU: Operation Excavation and Pre-processing

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Traditional LTU: Operation

- Moisture Control
- Tilling (aeration)
- Nutrients
- Lift Management Strategy

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Traditional LTU: Operation

- **Moisture Control: growth of microorganisms & hydrocarbon degradation rate depends on H_2O content**
  - **Too much water occludes air (O_2) from pore spaces**
  - **Not enough water limits bacterial growth**

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Traditional LTU: Operation

- **Moisture Control - optimum water content: 40-80% of field capacity**
  - **Field Capacity (FC): amount of water remaining in soil after saturating with water & allowing free water to drain**
  - **If FC = 20 g H_2O / 100 g dry soil, optimum water content = 8-16 g H_2O / 100 g dry soil**
  - **Qualitative – "the kick test"**
    - **Sticks to your boot – too wet**
    - **Dusts when kicked – too dry**

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Traditional LTU: Operation

- **Tilling Frequency**
  - **Microorganisms consume O_2, release CO_2**
  - **Maintain soil gas O_2 content at >2% by volume**
  - **Till about every 7-14 Days**

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Traditional LTU: Operation

Tilling Equipment

- Disk plow (shown below)
- Rotary tillers
- Sub-soiler plow

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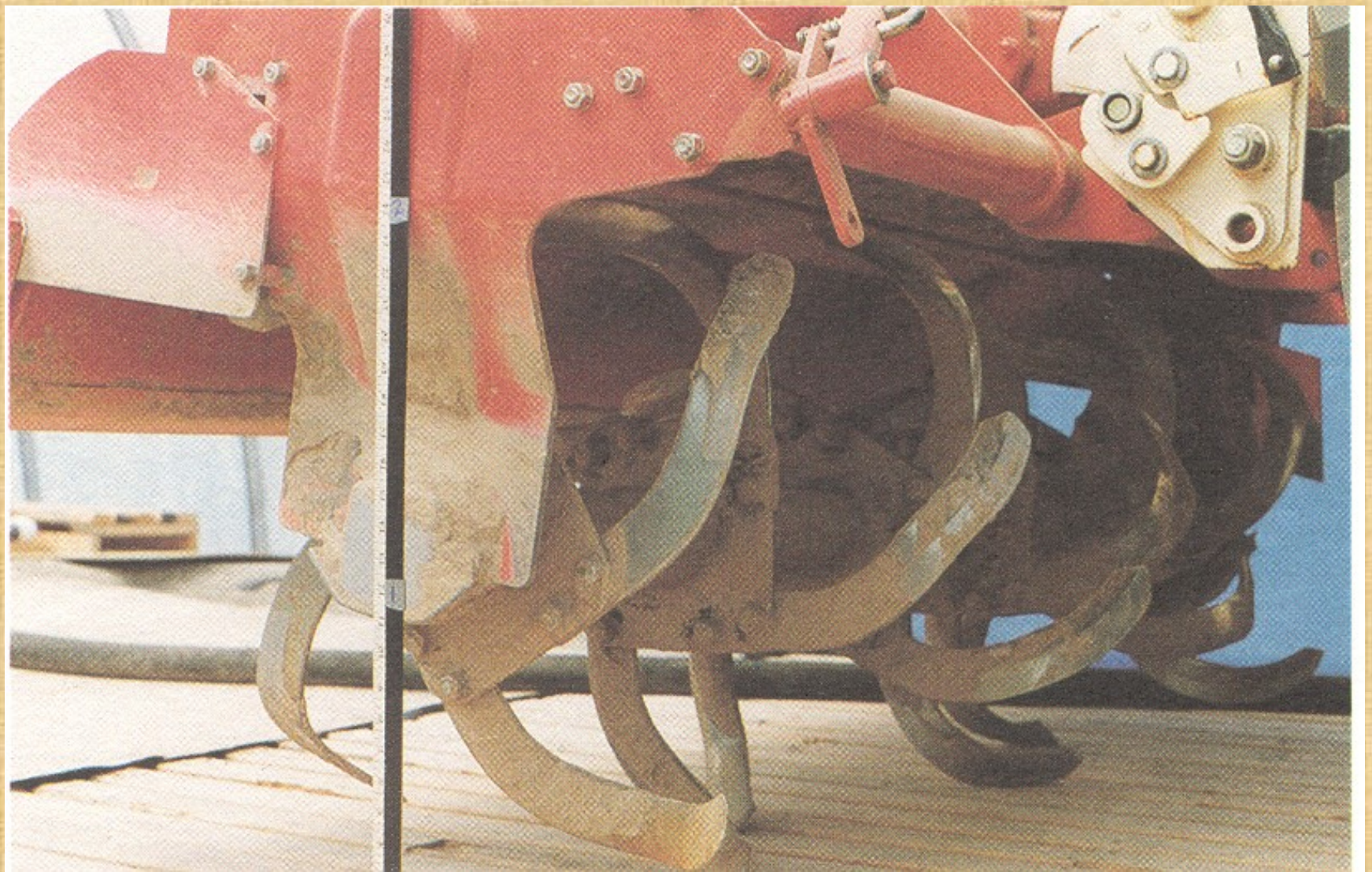
Rotary tiller



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Sub-soiler plow

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Traditional LTU: Operation

- **Nutrients**
- **Bacteria require nitrogen & phosphorous**
- **Carbon:Nitrogen:Phosphorous ratio (C:N:P) is used to estimate total fertilizer requirements**
  - **Typically use C:N:P ratio of 200:10:1**
  - **Maintain total N levels in soil at ~50 mg/kg**

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Traditional LTU: Operation Lift Management Alternatives

1. Move single lift of contaminated soil onto LTU, treat, remove from LTU, move next lift onto LTU
2. Move single lift of contaminated soil onto LTU, treat, leave soil on LTU, move next lift onto LTU
3. Move entire volume of soil to LTU. Treated soil is removed from LTU one lift at a time

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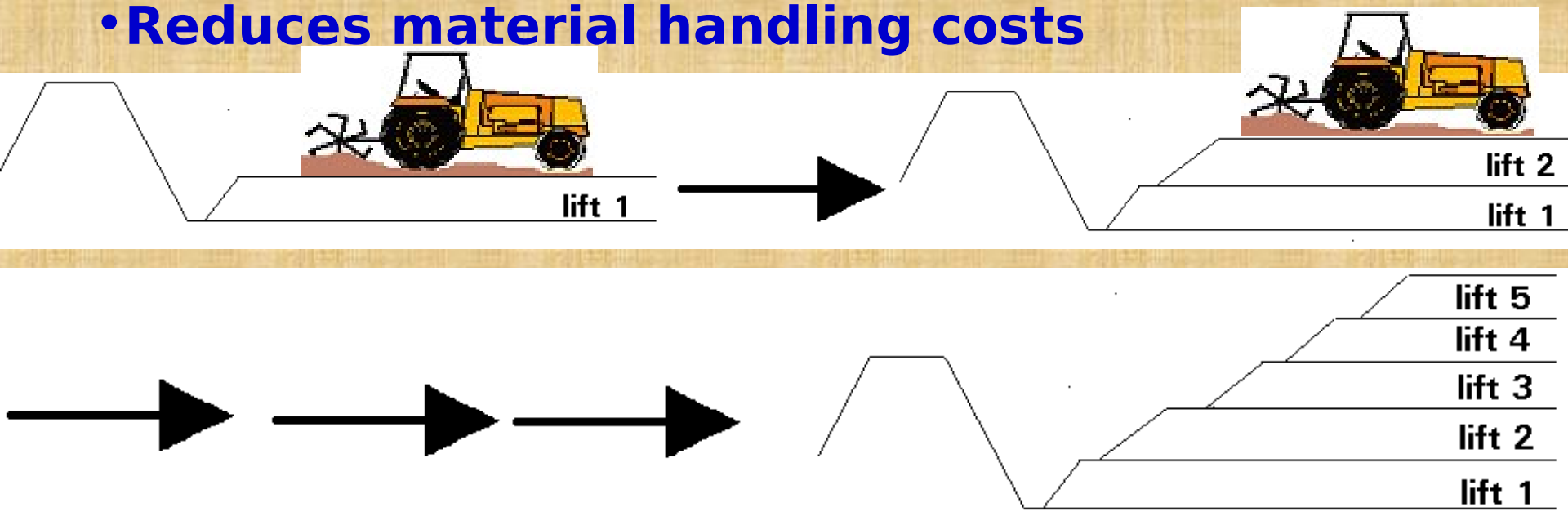
Traditional LTU: Operation

2. Treated soil remains on LTU

- **Reduces material handling costs**



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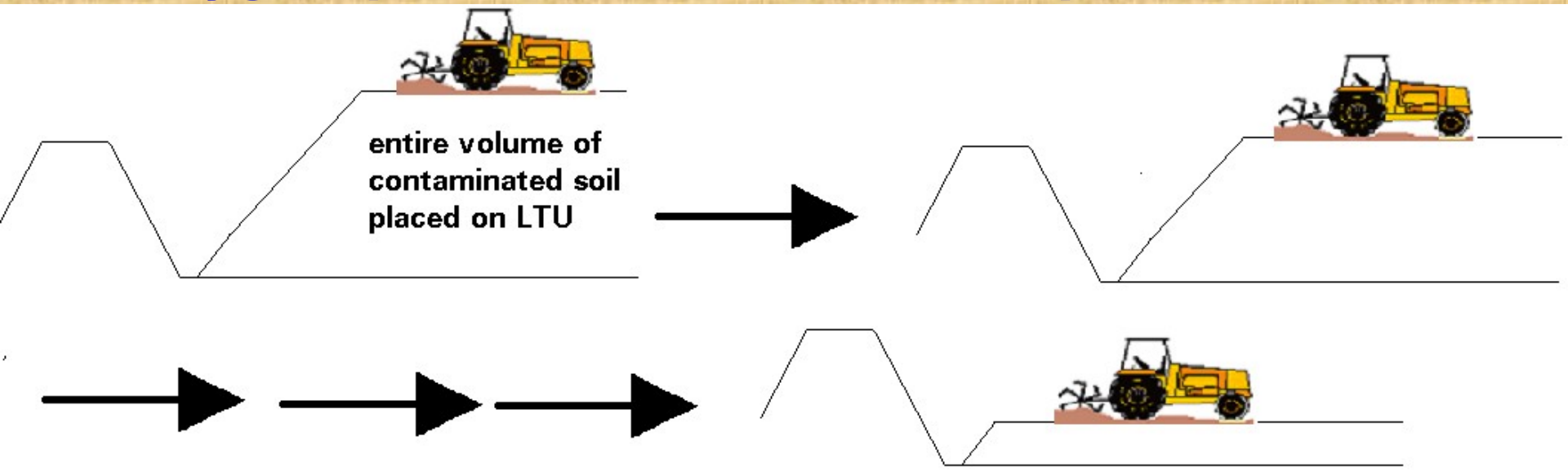
Traditional LTU: Operation

3. Entire volume of soil placed on LTU; treated soil is removed from LTU one lift at a time

- **Reduces total treatment time if nutrients and oxygen penetrate below the depth limit of**



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Low-Cost and Passive Land Treatment Strategies

- In-situ treatment
  - Applicability depends on site-specific factors
- Transition from active to passive
- Passive techniques
  - Reduced tilling frequency
  - Transition from landfarming to phytoremediation
  - Treatment has been shown to occur below depth limit of tilling equipment

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In-situ Land Treatment

With in-situ treatment there are risks of spreading contamination; but in-situ may be acceptable under the following conditions:

- **Sites where underlying groundwater is already contaminated.**
- **Depth to water table is >3 meters**
- **Hydraulic conductivity of underlying soils is $<1x10^{-5}$ cm/sec**
- **Site is outside of 25 year flood plain**

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In-situ Land Treatment

- Incorporation of organic amendments (e.g., manure) may help reduce leaching
- Berms & dikes should be constructed to control run-on and run-off
- In-situ treatment usually reduces material handling cost

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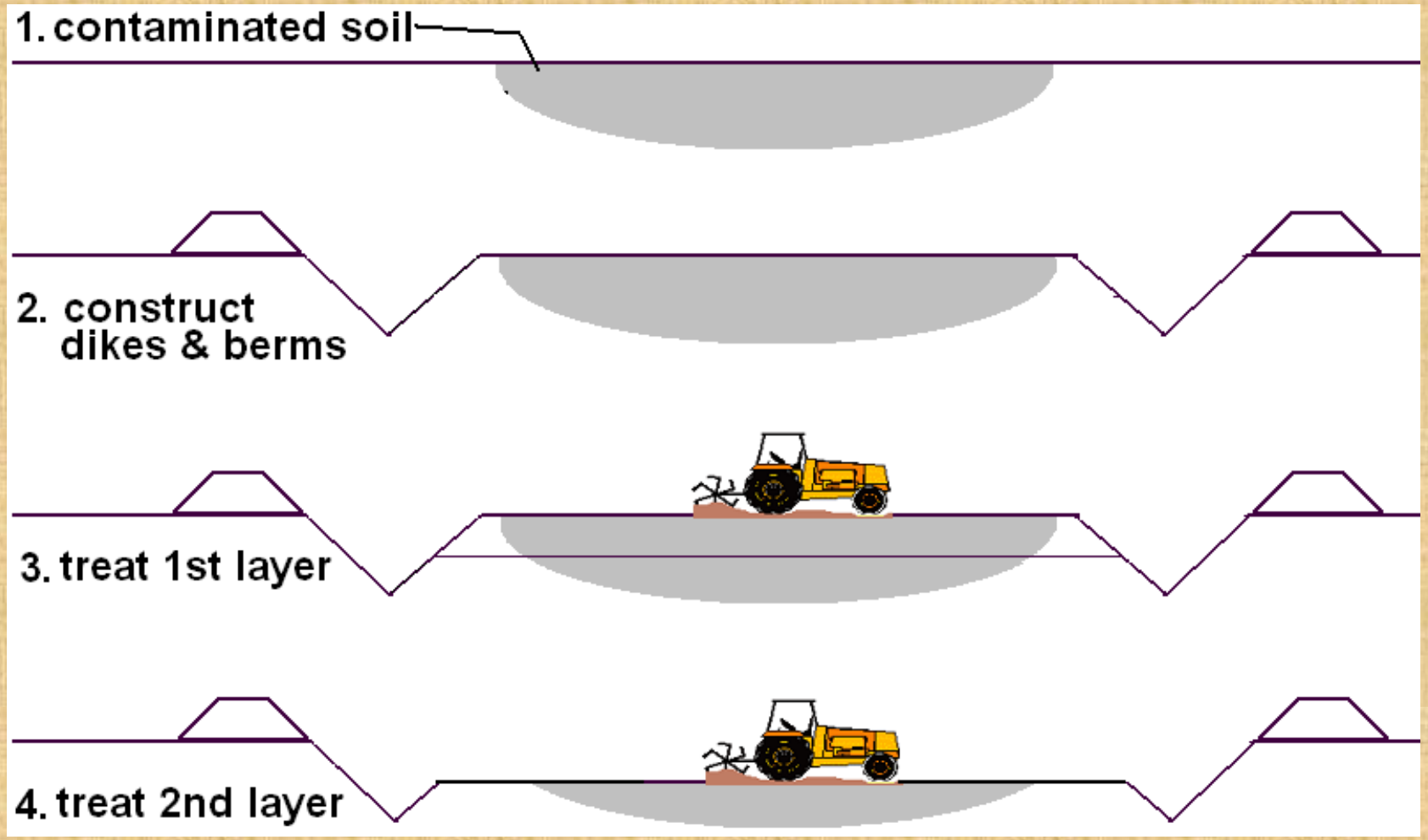
In-situ Land Treatment



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Passive Landfarming Strategies

1. Landfarm soil until it will support growth of forage crops
2. Transition to passive (e.g., grow forage crops for draft animals)
   - Potential for ingestion of contaminants that are taken up by plants
   - Heavy metals contaminated soils generally should not be used for forage crops due to potential for food-chain contamination

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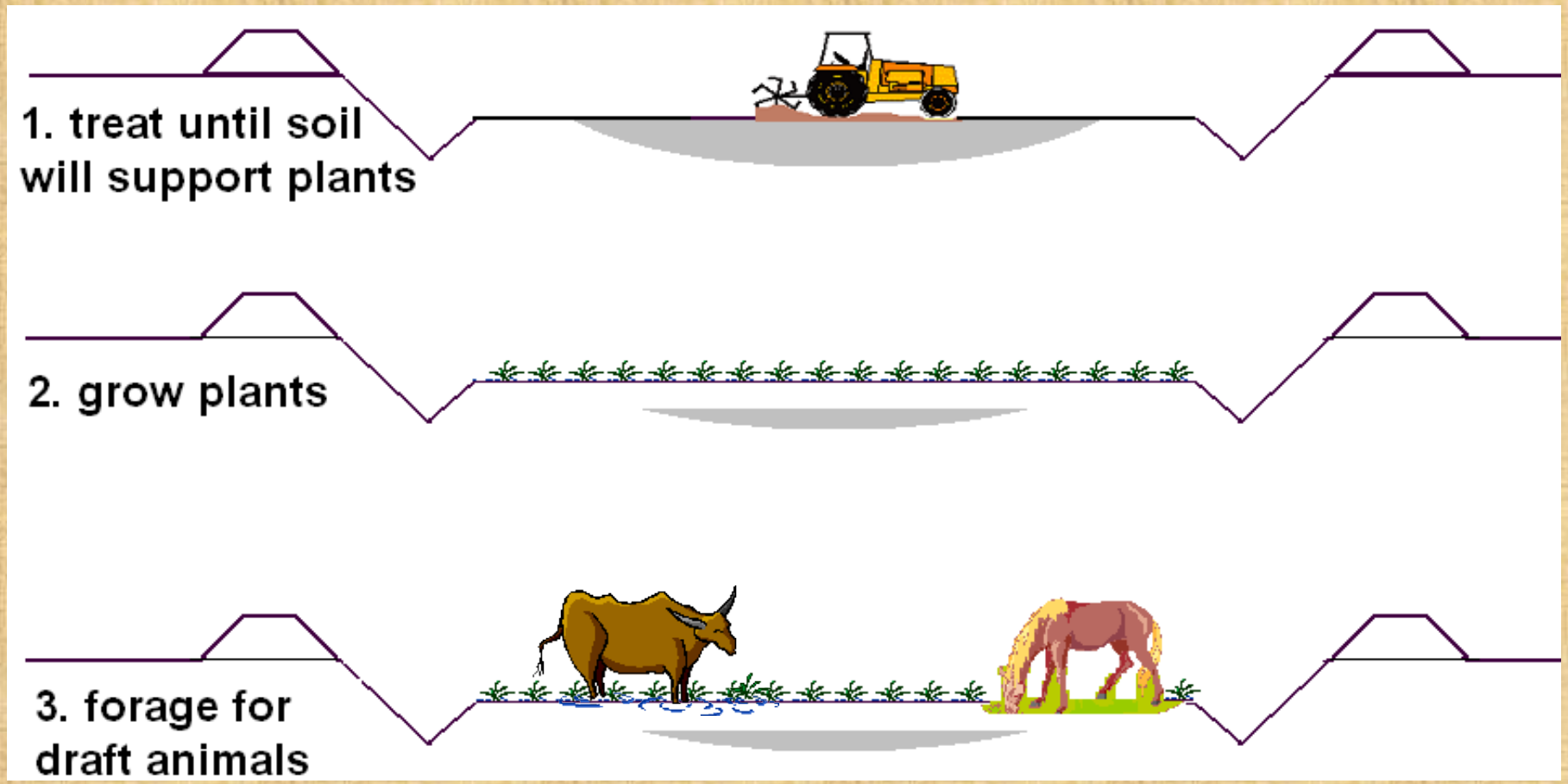
Passive Landfarming Strategies



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Conclusions

- Landfarming is capable of treating a wide range of contaminants at a reasonable cost & within a reasonable timeframe
- Land Treatment Units (LTUs) are used for ex-situ landfarming
  - LTU Design, Construction, & Operation
- Low Cost & Passive Land Treatment Strategies
  - Lift management can reduce material handling / treatment time
  - In-situ land treatment
  - Landfarming (active) → phytoremediation (passive)

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References and Free Internet Resources

- US Department of Defense Guide Specification:
  - BIOREMEDIATION OF SOILS USING LANDFARMING SYSTEMS: http://www.ccb.org/docs/ufgshome/pdf/02190.pdf

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References and Free Internet Resources

- **Federal Remediation Technologies Roundtable: http://www.frtr.gov/matrix2/section4/4_3.html#ref**

- **The following description of Landfarming is an excerpt from Chapter V of OUST's publication: http://www.epa.gov/swerust1/cat/landfarm.htm**

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Contact Information / Questions

- **U.S. Army Corps of Engineers**
  Hazardous, Toxic, and Radioactive Waste Center of Expertise Omaha, Nebraska, USA
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